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A study of
INSTRUMENTATION AND TELEMETRY CHECKOUT LANGUAGE
FINAL REPORT

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INSTRUMENTATION AND TELEMETRY CHECKOUT LANGUAGE

1.1 Language Objectives

The Acceptance, Test, or Launch Language (ATOLL) was developed to provide a language oriented toward real-time computer controlled testing of the Saturn missile systems. It has evolved into a language best suited for sequential control type testing where a stimulus is applied, a response tested, and the test advanced to the next point in the testing process. This type of language proves deficient in testing the instrumentation and telemetry systems where large amounts of data must be processed as it becomes available to the computer through the interface between the computer, the test equipment, and the stage systems.

Approximately 90% of the test procedures for the instrumentation and telemetry systems have been programmed in symbolic (machine) language, with ATOLL being used to provide preparatory and shutdown functions. The objectives of the automated tests were accomplished by symbolic code subroutines called in by the ATOLL execute (EXEC) operator.

Due to the inability of ATOLL to operate efficiently in the functional area of instrumentation and telemetry, this study was conducted to determine the feasibility of tailoring a language to instrumentation and telemetry requirements and to define the operators necessary for such a language.

1.2 Requirements

The operating characteristics and requirements of the checkout equipment were surveyed along with the functional requirements of the programs necessary to test the missileborne systems in compliance with MSFC testing philosophy. Accordingly, the functional requirements for the Instrumentation and Telemetry Checkout Language (ITCL) were developed.

Existing computer languages were surveyed to determine their applicability in solving the problems inherent in processing large quantities of data in real time. The major area of weakness in the existing languages, including ATOLL, is the lack of control of the peripheral equipment, particularly the magnetic tape units.

Due to the large amount of data to be put into the computer during a test sequence, the storage capacity of most machines would be quickly exceeded. This problem can be reduced by using the magnetic tape units as temporary data storage units.

An example of the magnitude of memory capacity required would be the Noise Level Test described in SR-QUAL-64-29-01. All measurements available through the DDAS (approx. 450) are sampled 32 times and averaged. Then each measurement is sampled 32 times and these 32 individual samples are compared to the average established in the first scan sequence. It can readily be seen that this amount of data would rapidly fill the high speed memory of most on-line machines.

The data acquired through the DDAS interface is available four (4) words at a time. The computer requests, by address, the desired data channel and receives the requested data, the data point preceeding the requested data and the two data points succeeding the requested data.

The RCA-110A stores these 4 words, packed two words each, in a 24 bit memory location. Therefore, sorting and unpacking must be part of the read (data access) operations in order to store the requested measurement data in a known and accessible location in memory. Any substitute machine must necessarily operate in a comparable manner.

The same type of support input data needed with the machine language test routines must be developed for the ITCL language routines. This will require the test engineer programmer to have more than rudimentary programming knowledge. This is not considered a disadvantage, as any limitations to a testing program should be from the hardware rather than the method or philosophy of utilizing the hardware.

1.3 Versatility

With these limitations and requirements a language capable of performing the necessary testing must be versatile. ITCL provides this versatility by making the control functions, performed during testing, program dependent; and by putting the required data into tables. For example, a READ statement requires an address table, a discrete flag table (if word contains discretes) and a storage area allocation table as arguments. These arguments may be entered with the initial program or may be entered from a magnetic tape unit during the operation of a program. This allows for rapid changes of the test procedure by changing the input address tables.

The simplicity of ATOLL, including the input format, is retained wherever possible. This is an advantage since the cognizant test engineers are only required to understand one language. The control of the external Instrumentation and Telemetry equipment can be accomplished by the use of the ATOLL "DISO" operator. The capability of constructing special operators (subroutines) is available in the ITCL language and in many cases is only dependent upon the ability of the programmer.

The support system is not defined by this study but must necessarily contain the compiler, a monitor control system and a post-test report generating system.

1.4 Example of ITCL

To demonstrate the versatility of ITCL a portion of a symbolic coded subroutine (TO 34) has been described using the ITCL operation. TO 34 is used to compare the same measurements using different transmission paths, PCM, DDAS, and PAM-RF. The example assumes that the required support systems have been implemented and the reference data is available on tape. The following operations would be performed by the example shown.

1. Reserve memory location for reading tapes and recording data.

2. Set up computer complex for recording of data using DDAS (600 KC) link.

3. Take 32 readings for each measurement, calculate average value, and record them on tape.

4. Repeat 2 and 3 using PCM-RF link.

5. Repeat 2 and 3 using PAM-FM link.

6. Compare DDAS and PCM-FM values and calculate if they agree within a selected tolerance.

7. Record those measurements which are out of tolerance.

ITCL CODING FORM

STEP NUMBER: STEP	SS	OPR.	CON	FIXED: VALUE	FIXED: LOWER LIMIT	FIXED: UPPER LIMIT	FIXED: UNIT	FIXED: TIME	VARIABLE	CARD NO.
ITCL										
		NAME							TOXX, 021567, SAMPLE	
		REMK							PAM/PCM COMPARISON FOR RUN	
			C						MODE	
MID		RESV	C	1800					MEASUREMENT NUMBER	
MEAS		RESV		900					MEASUREMENT AREA	
ATAB		RESV		900					ADDRESS TABLE	
DTAB		RESV		900					DISCRETE TABLE	
		STRT							EPCE, ITGE, ICE, RACU	
0010	02	MESG		GX	XX	XX			DISPLAY MESSAGE TO INSURE PROCEDURE	
									AND INPUT DATA IS AVAILABLE TO RUN	
									THIS PROCEDURE	
0010	08	TEST	Y						001012	
		REMK							THIS IS A MANUAL DELAY WHICH IS	
			C						RELEASED BY TEST CONDUCTOR	
		GOTO							001002	
0010	12	MESG		ERASE					CLEAR THE DISPLAY	
		SKIP	1	N			F		SKIP N FILES	
		ENTR	1						RE01, RE02	
		ENTR							(MID, RE02), (ATAB, RE01), (DTAB	
			C						, RE01)	
		REMK							READ IN REQUIRED DATA	
0010	20	SRCE		SXX	ATAB	RE01			SET SOURCE BITS TO 600KC	
0010	22	MODE							ALL, RUN	
0010	24	READ	1	32		RE01			ATAB, DTAB, MEAS	

ITCL CODING FORM (CONTINUED)

STEP NUMBER		OPR.		FIXED						CARD NO.
STEP	SS		CON	VALUE	LOWER LIMIT	UPPER LIMIT	UNIT	TIME	VARIABLE	
		WRIT	2						(MEAS, RE01)	
0010	30	SRCE		SXY	ATAB	RE01			SET SOURCE BITS TO RF	
0010	32	READ	1	32		RE01			ATAB, DTAB, MEAS	
		WRIT	2						(MEAS, RE01)	
		ENTR	1						(ATAB, RE01), (DTAB, RE01)	
		REMK							READ IN PAM REQUIRED TABLES	
0010	40	SRCE		SXZ	ATAB	RE01			SET SOURCE BITS TO PAM	
0010	42	READ	1	32		RE01			ATAB, DTAB, MEAS	
		WRIT	2						(MEAS, RE01)	
		BSR	2	3						
OTOI		RESV		900					OUT OF TOLERANCE FLAG	
KC		EQU		MEAS						
RF		EQU		ATAB						
PAM		EQU		DTAB						
		ENTR	2						(KC, RE01)	
		ENTR	2						(RF, RE01)	
		ENTR	2						(PAM, RE01)	
		REMK							READ IN DATA TO BE COMPARED	
0010	50	MESG		GX	XX	XX			DO YOU WISH TO CK KC VS RF	
			C						TO 1 PCT TOL ?	
0010	52	TEST	Y						001064	
0010	54	MESG		GX	XX	XX			SAME AS MESG 50 EXCEPT 2%	
0010	56	TEST	Y						001070	
0010	58	MESG		GX	XX	XX			SAME AS MESG 50 EXCEPT 3%	

ITCL CODING FORM (CONTINUED)

STEP NUMBER STEP	SS	OPR.	CONY	FIXED VALUE	LOWER LIMIT	UPPER LIMIT	UNIT	TIME	VARIABLE	CARD NO.
0010	60	TEST	Y						001076	
0010	62	GOTO							001080	
0010	64	PCT		1		900			KC, RF, OTOL	
0010	66	WRIT	2						(OTOL, RE01)	
0010	68	GOTO							001080	
0010	70	PCT		2		900			KC, RF, OTOL	
0010	72	WRIT	2						(OTOL, RE01)	
0010	74	GOTO							001080	
0010	76	PCT		3		900			KC, RF, OTOL	
0010	78	WRIT	2						(OTOL, RE01)	
0010	80			REPEAT FOR COMPARISON OF KC AND PAM						
				THEN ENTR RECORDS INTO COMPUTER TO FORMAT						
				AND OUTPUT AND PROCEDURE SHUT DOWN						

EXAMPLE NOTES

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MID		RESV	1800		Allocates space in memory and assigns label.
MEAS		RESV	900		
ATAB		RESV	900		
DTAB		RESV	900		
		STRT			Start of test procedure.
0010	08	TEST	Y		Requires yes response from test conductor to start test.
		GOTO			Sets up loop for TEST operator.
		SKIP	1 N	F	Data tape has been loaded on Tape Transport "1". This skips "N" files to position tape at beginning of desired data.
		ENTR	1		RE01, RE02. Read one record from Tape Transport "1" which has two words; store and identify as "RE01" and "RE02". ("RE01" is the number of measurements in the address table. "RE02" is twice "RE01" which will be the number of words in the Measurement Identification Table).
		ENTR	1		(MID, RE02), (ATAB, RE01), (DTAB, RE01). Read one record from tape transport 1. Store as many words as specified by the value of "RE02" in the "MID" table store the following words

						according to the value of "RE01" in "ATAB" and "DTAB" tables respectively.
0010	20	SRCE	SXX	ATAB	RE01	This will modify selected bit positions, specified by the value of "SXX", in each word of the address table (ATAB) which will *cause the computer to select the* DDAS 600 KC carrier as the source of these measurements.
0010	22	MODE				ALL, RUN. This will cause all the stage measuring adapters to be in the normal or "RUN" position by controlling the RACS.
0010	24	READ 1	32		RE01	ATAB, DTAB, MEAS. Read the values of as many measurements as specified by "RE01". The exact measurements are specified in the tables identified as "ATAB" and "DTAB". Take 32, samples of each measurement and calculate the average value. Store the average values in memory in the table "MEAS".
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		WRIT 2				Write in one record, on Tape Transport 2, the average values of the measurements. There will be RE01 words in this record.
0010	30	SRCE	SXY	ATAB	RE01	This will modify the selected bit positions specified by the value of SXY in the address table (ATAB) which will cause the computer to select the PCM-RF signal as the source of the measurements.

0010 40 SRCE SXZ ATAB RE01	Select the PAM-FM signal through the Telemetry Digitizing System as the source of the measurements.
BSR 2 3	(There have been three (3) records written on Tape Transport 2). This will back space the tape three (3) records so the data can be read back into computer.
OTOL RESV 900	This reserves 900 words in memory to be identified as OTOL. (This will be used to store which measurements are out of tolerance).
KC EQU MEAS RF EQU ATAB PAM EQU DTAB	Since the memory areas reserved for MEAS, ATAB, and DTAB are no longer used in this program they are reassigned as KC, RF and PAM respectively.
ENTR 2	(KC, RE01). Read one record from Tape Transport 2 and store information in "KC" table in memory. There are RE01 words in record. (This is DDAS data).
0010 50 MESG . . . 0010 60 TEST Y	This series of instructions allows the test conductor to select 1%, 2%, or 3% as the tolerance for comparing measurements.

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0010 64 PCT 1	KC, RF, OTOL. This compares the respective values in memory in tables "KC" and "RF" to see if they agree within 1% of full scale value. If measurement is out of tolerance the identification will be stored in the respective location of the

			"OTOL" table in memory. There are 900 comparisons to be made.
0010	66	WRIT 2	(OTOL, RE01). Record the "OTOL" table on Tape Transport 2. There will be one record with "RE01" words.

ITCL OPERATORS

2.1 Language Format

In defining the operators for the Instrumentation and Telemetry Checkout Language it is necessary to specify a format for the input data. Three alternatives were considered; define a new format, use "free" or compiler defined format as used in ATOLL II, or use the ATOLL format. Since the ATOLL format, a union between fixed fields and a variable field, would meet the requirements and was already used on the Saturn V program it was selected. In certain cases the labels on the fixed fields in ATOLL do not correspond to the intended use in ITCL, but this was not considered justification to define a new format.

2.2 Card Format

A special feature of the ATOLL system provides for multicard statements. A second card is always required for remarks. Allocations are as follows:

Card 1

Field	Column
Step	1 - 4
Sub-step	5 - 6
Operator	7 - 10
Condition	11
Value	12 - 19
Upper Limit	20 - 25
Lower Limit	26 - 31
Units	32 - 34
Time	35 - 42
Variable	43 - 70
Card Serialization	71 - 80

Continuation Cards

Field	Column
Blank	1 - 42
Variable	43 - 70
Card Serialization	71 - 80

Last Card

Field	Column
Remark	1 - 40
Blank	41 - 70
Card Serialization	71 - 80

2.3 ITCL Character Set

Alphabetic Characters, A - Z
Numbers, 0 - 9

Special Characters:	/ (slash)	+ (plus)
	, (comma)	. (period)
	- (minus)	( ) (parenthesis)
	* (asterisk)	(blank or space)
	= (equality)	$ (dollar sign)

Note:

An asterisk (*) after the mnemonic indicates that this operator is identical or similar to the ATOLL operator.

Operator: DELAY Mnemonic: DELY*

Class: CONTROL

Description:

The DELAY operator will cause a delay in execution of the sequence of test statements until a specified time has elapsed.

Fixed Fields:

Operator Field:

The mnemonic DELY will be entered.

Time Field:

The desired time delay will be entered in milliseconds.

All other fields will be left blank.

Operator: EXECUTE Mnemonic: EXEC *

Class: CONTROL

Description:

The EXECUTE operator will initiate an unconditional branch (transfer) to an independent subroutine. This subroutine can be coded in either ITCL or machine language. It must be located on a library tape or card deck that is accessible to the loader. The return from the named subroutine will be to the next executable statement following the Execute statement.

Fixed Fields:

Operator Field:

The mnemonic EXEC will be entered.

Value Field:

The symbolic name of the subroutine, which must contain not more than 4 alphanumeric characters. This name will be left justified and the first character must be alphabetic.

All other fields will be left blank.

Variable Field:

The list of arguments, if needed, will be entered separated by commas as delimiters.

Operator: GO TO   Mnemonic: GOTO*

Class: CONTROL

Description:

The GO TO operator will cause an unconditional branch to a location specified in the variable field.

Fixed Fields:

Operator Field:

The mnemonic GOTO will be entered.

All other fixed fields will be left blank.

Variable Field:

The desired branching symbolic address, the Step and Sub-step numbers of the location to be branched to, will be entered. The sequence number displayed on the CRT will be that of the step transferred to.

Operator: <u>MODE SELECT</u> Mnemonic: <u>MODE</u>

Class: <u>CONTROL</u>

Description:

The MODE SELECT operator provides means to set the RACS in the desired mode.

Fixed Fields:

<u>Operator Field:</u>

The mnemonic MODE will be entered.

All other fixed fields will be left blank.

Variable Field:

The RACS code (system, rack, and channel) selected will be entered for a specific channel. The word "ALL" will be entered if all RACS are desired to be controlled. The desired mode (HIGH, RUN, LOW) will be entered following the selection code. These two entries are to be separated by commas.

Operator: <u>START</u> Mnemonic: <u>STRT</u>

Class: <u>CONTROL</u>

Description:

The START operator will identify the starting point of the executable portion of a Test Program and will specify those items of test equipment which are required to be in the Automatic Mode for successful execution of the program. The START operator will generate code that will check that these equipment items are in Automatic Mode. If these items are not in Automatic Mode, a message will be displayed stating the fact and giving the status of the items involved. The Test Conductor will have the options of rechecking the status of these items, of accepting the present status as proper, or of obtaining the full set of options allowable at the START Hold Point.

The specification of items of equipment which are required to be in the Automatic Mode is, with two exceptions, also a specification of those Test Step Indicators which are to be used to display the progress of the Test Program. The exceptions are:

1) The Test Step Indicator associated with the Control and Monitor Console will be used by all programs.

2) There is no Test Step Indicator associated with either the Hydraulic Control Equipment or the Remote Automatic Calibration Unit.

The START operator will generate code which accomplishes setting the Test Step Indicators to zero.

The START operator will also generate code which saves the conditions of the Discrete Outputs, the Discrete Input Prediction Profile, and the Analog Outputs for the purpose of restoring these conditions when necessary.

An entry on the Event Trail Data Tape will be caused by this ITCL operator.

Fixed Fields:

<u>Operator Field:</u>

The mnemonic STRT will be entered.

Variable Field:

The designations of those items of equipment which are required to be in Automatic Mode will be entered. For the purposes of ITCL, these designations will be defined prior to implementation. If no designations are entered into the Variable Field, the ITCL Translator will assume that all items of equipment are specified. Entries in the Variable Field will be separated by commas.

Operator: <u>SOURCE SELECT</u> Mnemonic: <u>SRCE</u>

Class: <u>CONTROL</u>

Description:

The SOURCE SELECT operator will modify the address table to provide the proper source code bits in the address being compared in the DDAS interface. This will allow for standard address tables in many cases.

Fixed Fields:

<u>Operator Field:</u>

The mnemonic SRCE will be entered.

<u>Value Field:</u>

The variable SO1, SO2, etc., will be entered. These variables must be defined in a dictionary that is available to the programmer.

The lower limit field contains the location of the address table.

The upper limit field contains the length of the address table.

All other fixed fields will be blank.

NOTE:
Comments may be entered in the variable field as an aid to the programmer.

Operator: TEST Mnemonic: TEST*

Class: CONTROL

Description:

The TEST operator will cause a transfer to be made to a succeeding ITCL statement within the same block if a specified condition is met. The succeeding statement to which the transfer is made is specified in the variable field. If the condition is not met, the next ITCL statement following TEST will be taken. The branching condition to be met may be one of the following:

1. The result of evaluating a Boolean expression involving multiple discretes and/or flags.

2. The reply made by the Test Conductor at the Control and Monitor Console.

Additionally, a time period may be specified in which to have the condition met for case 1 and 2 above. An entry on the Event Trail Data Tape will be made by this ITCL statement. This statement will provide for any reference ground, analog-in, or telemetry switching required. Also, this statement will provide for gauge and absolute pressure transformations as required.

Fixed Fields:

Operator Field:

The mnemonic TEST will be entered.

1. Boolean Conditional Branching

All fixed fields except the condition and time fields will be left blank.

Condition Field:

"0" - False condition. If the Boolean expression is false (0), then the condition is met and the transfer to the specified address is made. If the Boolean expression is true (1), then the condition is not met and the next statement is taken.

"1" - True Condition. If the Boolean expression is true (1), then the condition is met and the transfer is made. If the Boolean expression is false (0), then the condition is not met and the next statement is taken.

Time Field:

If a time period is required for the condition to be met, the time in milliseconds will be entered. This time period provides testing for the "met" condition until the time elapses. If the condition is "not met" in this period, the next statement is taken. If no time is specified, the condition to be met is tested only once.

Variable Field:

The address to which the transfer is made, if the condition is met, is entered alphanumerically. Following the address, the Boolean expression, consisting of a mixture of discrete-ins and/or flags, will be entered. The address and the Boolean expression must be separated by a comma.

2. Test Conductor Reply Branching

The test conductor will be given the option of replying "YES" or "NO" by means of the display summary buttons. The test conductor must make a reply in order to proceed.

Fixed Fields:

Condition Field:

"Y" - A test conductor reply of "YES" constitutes a met condition. A "NO" answer constitutes a not met condition.

"N" - A test conductor reply of "NO" constitutes a met condition. A "YES" answer constitutes a not met condition.

Variable Field:

The address to which the transfer is made, if the condition is met, is entered alphanumerically.

Operator: ACQUIRE Mnemonic: PCU

Class: RESPONSE

Description:

This operator provides the capability of communication between the test engineer and the computer during tests utilizing the PCU's. It is a general representation of the subroutine used to adjust the DC signal conditioners and is input table (variable field) dependent.

Fixed Fields:

Operator Field:

The mnemonic PCU will be entered.

Condition Code:

Enter an "R" if Run mode only is tested. Enter "A" if all Modes "RUN", "HIGH", "LOW", are tested.

Value Field:

The length of the tables entered in the variable field will be entered.

Variable Field:

The following storage location labels will be entered separated by commas. These tables must be entered previously via an ENTER statement.

1 - Measurement ID

2 - Legal address (octal)

3 - DDAS address table

4 - RACS address table

5 - Predicted RUN value tables

6 - Predicted LOW value tables

7 - Predicted HIGH value tables

Operator: <u>DISCRETE INPUT</u> Mnemonic: <u>DISI*</u>

Class: <u>RESPONSE (PREDICTION)</u>

Description:

The DISCRETE INPUT operator will cause changes in the discrete input prediction profile table.

Fixed Fields:

<u>Operator Field:</u>

The mnemonic DISI will be entered.

<u>Condition Field:</u>

The condition shall be "1" for ON and "0" for OFF.

All other fixed fields will be blank.

Variable Field:

The addressed discrete-ins (DIxxxx) will be entered. A minus sign may not precede the "DI" prefix. Each address shall be separated by a comma.

Operator: READ   Mnemonic: READ

Class: RESPONSE

Description:

The READ operator will initiate a single or multiple sampling of the addressed input channel or channels. This statement, with its arguments, provides for any ground or analog-in switching required.

Fixed Fields:

Operator Field:

The mnemonic READ will be entered.

Condition Field:

A "1" entry will indicate that samples (quantity entered in value field) of each item in the address table (in variable field) is accumulated and averaged. A "0" entry will indicate that a sample of the measurement named in the variable field will be taken. If a tolerance check is desired, this READ operator must be followed by a COMP operator.

Value Field:

If the condition field entry is "1", the number of times each item of the address table is to be read, accumulated and averaged will be entered in decimal notation. If "0" was entered in the condition field, this field will be left blank.

Lower Limit:

Leave blank.

Upper Limit:

If the condition field entry is "1", the number of measurements (length of address table) to be taken is entered in decimal notation. If "0" was entered in the condition field, this field will be left blank.

Unit Field:

An "A" is entered if the measurement is to read through the computer controlled A/D converters. If data is to be acquired through the DDAS interface, this field will be left blank.

Variable Field:

If the condition field entry is a "0", the address of the device being sampled will be entered--followed by the address where the sample is to be stored. If the condition field entry is a "1", the label of the address table, discrete flag table, and storage location will be entered--separated by commas. All tables and storage addresses must have been reserved by a RESV operator. The discrete table will be used to separate the discrete words so that rather than be accumulated and averaged, it will be counted to indicate how many times it was as expected and how many times it was different than expected. This count will be stored in the cell location allocated for the specific discrete word.

Operator: SCAN Mnemonic: SCAN*

Class: RESPONSE

Description:

The SCAN operator will scan all discrete inputs and make a comparison of these with a reference profile* of the discrete conditions. Discrepancies in this comparison will constitute NO-GO conditions, subject to the restrictions of the Limited SCAN and Critical SCAN modes of operation as defined below. If a NO-GO condition exists, the status of the erroneous discretes, the test program's sub-step, step, block, and name will be output onto the display and the line printer. Following the output of the NO-GO conditions, a program transfer to the NO-GO options will occur. A storing location can be specified with this statement to save the status of the error profile** and the actual input discrete conditions. An automatic entry on the Event Trail Data Tape is provided for each scan execution. (This statement can be time delayed, where the delay is the time between the start of the statement execution and the time the scan is commenced.)

Definition of Critical and Limited Scan modes of operation:

1. Critical Scan Mode - In the Critical Scan Mode, the Scan operator will not consider as NO-GO conditions discrepancies between the reference profile and the discrete inputs for those discrete inputs which the test conductor has specified as non-critical via inputs through the Control and Monitor Console.

2. Limited Scan Mode - In the Limited Scan Mode, the Scan operator will consider as NO-GO conditions discrepancies between the reference profile and the discrete inputs for only those discrete inputs which have been specified in DISI Statements which have been executed after the Limited Scan Mode was put into effect.

*A Discrete-in Prediction Profile which was previously set by DISI statements.

**A table of discrepancies between the actual discrete-in conditions and the Discrete-in Prediction Profile as modified by the Critical and Limited Scan modes.

Fixed Fields:

Operator Field:

The mnemonic SCAN will be entered.

Time Field:

If a time delay is used, time in milliseconds will be entered.

All other fixed fields will be blank.

Variable Field:

The storing location, if used, will be entered. A declaration of the storing address must be made somewhere in the test program by the use of the RESV operator.

Operator: ANALOG RAMP Mnemonic: RAMP*

Class: STIMULATION

Description:

The ANALOG RAMP operator will cause the application of a ramp function to one addressed analog device. The ramp will be linear* with the slope defined by the Upper and Lower Limits and the Time Duration. This operator will provide for any reference ground switching necessary. Also, this operator will provide for gauge and absolute pressure transformations as required.

Fixed Fields:

Operator Field:

The mnemonic RAMP will be entered.

Condition Field:

Left blank.

Value Field:

The signed value of the increment for the RAMP will be entered.

Lower Limit Field:

The signed value of the starting point of the RAMP will be entered.

Upper Limit Field:

The signed value of the end point of the RAMP will be entered. The end value actually reached by this statement depends upon the entries made in this field, the previous two fields, and the time fields. (See usage below). The value reached will remain applied to the addressed device upon termination of the operation.

Units Field:

The mnemonic of the type of analog stimulation (VDC, CPS, PSI, etc.) will be entered.

*The ramp will be approximated by applying incremental steps.

Time Field:

The time duration of the RAMP will be entered in milliseconds. A minimum time will exist for the RAMP time duration which again depends upon this field and the value, lower limit and upper limit fields (see usage below).

Variable Field:

The address for the analog devices (AOXX) will be entered.

Usage:

The following points need to be considered for RAMP usage. The number of steps (N_S) and a time increment per step (Δt) are to be determined as follows:

N_S - $\frac{UL - LL}{\Delta v}$ where N_S is rounded to the nearest integer.

Δt - $T / \frac{(UL - LL)}{\Delta v}$

UL - RAMP end point entered in Upper Limit Field.

LL - RAMP starting point entered in Lower Limit Field.

v - Increment value entered in Value Field.

T - Time entered in Time Field.

Restrictions:

$\Delta t \geq 0.59$ ms must hold; if $\Delta t < 0.59$ ms then 0.59 ms will be the time increment used per step. When $\Delta t > 0.59$ ms holds, the value of Δt used will be in integral multiples of 0.1 ms. This will establish a minimum time for the RAMP duration which depends of course upon the number of steps. $\Delta v \geq 0.1\%$ full scale must hold for the RAMP increment.

Regardless of the initial condition of the analog device, the RAMP operator will produce an immediate analog step to the starting point (LL) and then begin incrementing by Δt in time and Δv in the ordinate to a value approximating the end point (UL). The end point will be reached in a time approximating the time entered in the time field as follows: $t_f - N_S \cdot \Delta t + t_i$ thus $t_f - t_i - T$ where t_f is the final time and t_i is the initial time.

Operator: ANALOG STEP   Mnemonic: ALOG *

Class: STIMULATION

Description:

The ANALOG STEP operator will cause the application of an analog step value to the addressed device. The addressed device will be stepped from its initial condition to the value specified in the value field. This operator will provide for any reference ground switching necessary. Also, this operator will provide for gauge and absolute pressure transformations as required.

If a time in milliseconds is stated the step will be applied for that amount of time and then removed. If no time is stated the step will be applied for an indefinite period of time (i.e., until another ALOG instruction with the same address is executed).

Fixed Fields:

Operator Field:

The mnemonic ALOG will be entered.

Value Field:

The value of the analog stimulation which is to be applied will be entered.

Units Field:

The mnemonic of the type of analog stimulation (VDC, PSI, etc.) will be entered.

Time Field:

If a time dependent pulse is desired, the time shall be entered in milliseconds.

All other fixed fields will be blank.

Variable Field:

The addressed unit code (AOxx) will be entered.

Operator: DISCRETE OUTPUT Mnemonic: DISO *

Class: STIMULATION

Description:

The discrete lines are arranged into groupings of 24 discretes referred to as a word. These words are grouped into a discrete output profile table. The DISCRETE OUTPUT operator causes changes in the discrete output profile words and transmits these changed words over the discrete output lines. * The transmitted discrete changes may be time dependent. This time dependency will be the duration of the specified condition. If no time is specified, the condition is absolute. An entry on the Event Trail Data Tape will be made by this ITCL operator.

Fixed Fields:

Operator Field:

The mnemonic DISO will be entered.

Condition Field:

The following entries will be made:

"0" - indicates an "OFF" condition.

"1" - indicates an "ON" condition.

Time Field:

If time dependency is used, time will be entered in milliseconds.

The other fixed fields will be blank.

Variable Field:

Entries will be the addressed switching devices identified by the discrete integer number prefixed by a "DO". A minus sign may precede the "DO" prefix of a discrete integer number in order to complement the condition field entry. Each address will be separated by a comma. The address string may be continued to additional cards by specifying a "C" in the condition field.

*All 24 discrete outputs comprising a word will be transmitted when any one or more of the discrete outputs in that word are changed.

Operator: ALGEBRAIC COMPUTATION   Mnemonic: ALGE*

Class: UTILITY

Description:

The ALGEBRAIC COMPUTATION operator will cause the algebraic expression listed in the variable field to be evaluated such that the result of the operations listed to the right of the equal sign is stored in the memory cell listed to the left of the equal sign.

Fixed Fields:

Operator Field:

The mnemonic ALGE will be entered.

Condition Field:

If condition field is left blank, straight algebra will be performed.
If a B is entered, logical Boolean algebra will be performed.

All other fixed field will be left blank.

Variable Field:

The first entry will be the labeled memory cell in which the result of the evaluated algebraic expression is to be placed. The second entry will be the algebraic expression to be evaluated. These two entries will be separated by an equal sign. The expression may be continued in the variable field of continuation cards.

Usage:

Rules for Writing Algebraic Expressions

An algebraic expression will consist of one or more terms. Two or more terms will be separated by the addition or subtraction operators. A term will be composed of one or more elements. Two or more elements will be separated by the multiplication or division operators. An element will be composed of a constant, a variable, a function of a variable or constant, or another expression. Two algebraic operators may not appear next to each other.

1. Operations   The following four operations are provided for algebra:

Addition	+
Subtraction	-
Multiplication	*
Division	/

The following three Boolean operations are provided:

*	logical	AND
+	logical	OR
-	logical	NOT

2. Function   The following elementary functions are provided:

SIN: Computes the sine of the argument where the argument is expressed in radians.

COS: Computes the cosine of the argument where the argument is expressed in radians.

TAN: Computes the tangent of the argument where the argument is expressed in radians.

ATN: Computes the arctangent in radians of the argument.

** : Exponentiation - Raises the first argument to the power given by the second argument. The second argument must be a positive decimal integer (without the decimal point).

SQRT: Extracts the square root of the argument.

LOGE: Finds the log to the base e of the argument.

- : Negation - Finds the negative of the argument.

3. Variables   A variable is given by any symbol having one to four alphanumeric characters, the first of which must be alphabetic. The following characters cannot be used to form variables:

+ plus	- minus	. dot
* asterisk	/ slash	$ dollar sign
— dash	= equal sign	(left parenthesis
) right parenthesis	, comma	

4. Constants A constant is any sequence of five or less numeric characters and a decimal point. A power of 10 (expressed as E ± xx) may follow the number. A constant may be preceded by a + or - sign. The constant in absolute value must be less than 10^{38} and greater than 10^{-37}.

Operator: BACKSPACE RECORD Mnemonic: BSR

Class: UTILITY

Description:

The BACKSPACE RECORD operator will cause the specified tape unit to backspace the requested number of records. In order that the location of the read heads is known on the specified tape and tape unit, an ENTR operator must be used prior to the BSR operator in the test procedure.

Fixed Fields:

Operator Field:

The mnemonic BSR will be entered.

Condition Field:

The number specified to identify the desired tape unit will be entered.

Value Field:

The quantity of records to be backspaced will be entered in decimal notation.

All other fixed fields and the variable field will be left blank.

Operator: CHECK Mnemonic: CHCK

Class: UTILITY

Description:

The CHECK operator provides looping capability when used in conjunction with an ALGE operator. It will compare the quantity entered in the Value Field with the variable entered in the lower limit field and branch according to the arguments entered in the variable field.

Fixed Fields:

Operator Field:

The Mnemonic CHCK will be entered.

Value Field:

The quantity (count) of the loop will be entered.

Lower Limit:

The label of the left hand side of the equation in a preceding ALGE operator.

All other fixed fields are left blank.

Variable Field:

The location in the program to be branched to if the argument in the Value Field is less than the value in the Lower Limit Field, followed by the location in the program to be branched to if the two arguments are equal, followed by the branch location if the first is greater than the second. These locations will be separated by commas.

Operator: CLEAR Mnemonic: CLR

Class: UTILITY

Description:

This operator provides the capability to zero out and enter bit configurations into selected memory locations. An example of its use would be when comparing two data tables, items of data that would be meaningless if compared, may be replaced with a N/A flag.

Fixed Fields:

Operator Field:

The mnemonic CLR will be entered.

Condition Field:

A zero will be entered if the variables entered in the variable field are items rather than arrays. A one will be entered to signify arrays.

Value Field:

The desired bit configuration will be entered in octal notation.

Upper Limit:

If a one (1) is entered in the condition field, the quantity, in decimal notation, will be entered left justified. An individual CLEAR operator must be made of arrays of different lengths. If the condition field is zero, no entry will be made.

All other fixed fields will be blank.

Variable Field:

A list of the variables will be entered separated by commas. Continuation cards are acceptable.

Operator: <u>COMPARE</u> Mnemonic: <u>COMP</u>

Class: <u>UTILITY</u>

Description:

This operator provides the means to compare data to see if it is within the specified tolerance.

Fixed Field:

<u>Operator Field:</u>

The mnemonic COMP will be entered.

<u>Condition Field:</u>

If a "0" is entered, the addressed data in the variable field will be checked to see if it is within the values entered in the upper and lower limit fields. If a "1" is entered, the two data arrays entered in the variable field will be compared item by item to see if they agree ± the tolerance value entered in the value field.

<u>Value Field:</u>

If condition field is "1" enter the tolerance desired in millivolts. If "0" leave blank.

<u>Lower Limit Field:</u>

If condition field is "0" enter the lower tolerance limit. If "1" leave blank.

<u>Upper Limit Field:</u>

If condition field is "0" enter the upper tolerance limit. If "1" enter the length of the data arrays named in the variable field.

Variable Field:

If condition field is "0", the address of the data to be compared will be entered followed by the storage location label for the out of tolerance sample.

If the condition field is "1", the label of the first data array will be entered followed by the label of the second data array and the storage location label for the out of tolerance samples. All the above entries will be separated by commas.

Operator: <u>CONVERT</u> Mnemonic: <u>CONV</u>

Class: <u>UTILITY</u>

Description:

This operator provides a means to convert the data from its voltage representation to engineering units prior to processing for display.

Fixed Fields:

<u>Operator Field:</u>

The mnemonic CONV will be entered.

<u>Condition Field:</u>

A "0" will be entered if the output of the data device is linear. A "1" will be entered if non-linear. A "T" will be entered if an array of data points are to be converted.

<u>Value Field:</u>

Enter the offset if it exists.

<u>Lower Limit Field:</u>

If condition field is "0", the lower limit coordinate of the curve will be entered. If "1" or "T", leave blank.

<u>Upper Limit Field:</u>

If condition field is "0", the upper limit coordinate of the curve will be entered. If "1", leave blank. If condition field is "T" enter number of measurement to be converted.

<u>Unit Field:</u>

The engineering unit ID will be entered (ie, PSI, VDC, etc.).

Variable Field:

If condition field is "0", enter the data address and the storage address separated by commas. If "1", the same as "0", but at the end point values of the piecewise linear curve. If condition field is "T", enter the data array address, the table containing the scale factor for each address, and the storage address, separated by commas.

Operator: <u>DATA</u>   Mnemonic: <u>DATA</u>

Class: <u>UTILITY</u>

Description:

The DATA operator provides the means of entering predefined constants into selected memory locations in the core memory of the computer.

Fixed Fields:

<u>Operator Field:</u>

The mnemonic DATA will be entered.

<u>Step Field:</u>

The label of the data defined will be entered.

<u>Sub-Step Field:</u>

The subscript of the label will be entered, if required.

<u>Condition Field:</u>

The following symbols will be entered to define the type of Constant.

a. H BCD information

b. B Boolean constants (true or false)

c. D Decimal fixed point integers

d. O Octal information

e. F Floating point decimal information

<u>Value Field:</u>

The constant that the label requests to be stored will be entered.

All other fields are to be left blank.

Operator: END   Mnemonic: END*

Class: UTILITY

Description:

The END operator will be used to close a named Test Procedure, and is used to terminate the complier.

Fixed Fields:

Operator Field:

The mnemonic END will be entered left justified.

All other fixed fields will be left blank.

Variable Field:

Left blank.

Operator: ENTER Mnemonic: ENTR

Class: UTILITY

Description:

The ENTER operator will provide the means to read data into the computer memory from the magnetic tape units and the card reader. The data will be stored in the named locations as defined by previous RESV and/or EQU operators.

Fixed Fields:

Operator Field:

The mnemonic ENTR will be entered.

Condition Field:

Entry of a 0 (zero) will cause the card reader to be read into memory. A number greater than zero will cause the tape unit that is identified by that number to be read.

Value Field:

The value field will be used to define the format of the data to be read into the computer. If no entry is made, the format will be binary. If the data is octal or BCD, an O or D will be entered.

All other fixed fields will be left blank.

Variable Field:

The variables to be entered as arguments are to be separated by commas as delimiters. If the argument is enclosed in a set of parenthesis, the first item is the name of the variable array which has been previously defined by a RESV statement. The second item is either the name of the location where the quantity to be read is to be stored or is the numeric quantity to be read in. This number must be less than or equal to the reserved quantity. If the variables are not enclosed in parenthesis, they are individual items.

Note: Single subscripting of variables is allowed.

Operator: <u>EQUIVALENCE</u> Mnemonic: <u>EQU</u>

Class: <u>UTILITY</u>

Description:

The EQUIVALENCE operator will provide for the equating of two variable names to the same storage allocation. These variable names must be entered previously with a RESV operator.

Fixed Fields:

The label of the second variable will be entered in the value field, left justified. The characteristics of the second variable are the same as describe the first variable.

<u>Operator Field:</u>

The mnemonic EQU will be entered.

<u>Step Field:</u>

The name (label) of the first variable will be entered. The label may consist of up to 4 alphanumeric characters, the first being alphabetic.

All other fields will be left blank.

Operator: FORMAT Mnemonic: FRMT

Class: UTILITY

Description:

60 character positions are available for display output and 120 character positions are available for line printer output.

Fixed Fields:

Operator Field:

The mnemonic FRMT will be entered.

Step Field:

The label of the format description will be entered.

Sub-step Field:

Left blank.

Condition Field:

A continuation card can be used.

Remaining Fields:

(Col 12 through 70) The format description will be entered consisting of the following elements separated by commas:

(a) BCD information - (xxByyyy--)

The number of BCD characters followed by B followed by the BCD information constitutes the BCD element. The number of BCD characters used must be a multiple of 4.

(b) Octal Information - (Oxx)

The prefix "o" attached to the number of character positions desired for the field width of the octal output information constitutes the octal element. The octal information will be right justified in the field. The field width must be at least 9 characters.

(c) Decimal Integer Information - (Dxx)

The prefix "D" attached to the number of character positions desired for the field width constitutes the decimal element. The binary number in the computer will be converted to a decimal integer and right justified in the field. The field width must be at least 9 characters.

(d) Floating Decimal Information - (Fxx)

The prefix "F" attached to the number of character positions desired for the field width constitutes the floating decimal element. This field width must be at least 12 characters to accommodate the output format ± X.XXXXE+XX. The output format will be right justified in the field.

(e) EST information - (Txx)

The prefix "T" attached to the number of character positions desired for the field width constitutes the EST element. This field width must be at least 12 characters to accommodate the output format of XX:XX:XX.XXX. The output format will be right justified in the field.

(f) Skip position - (Xxx)

The prefix "X" attached to the number of characters position to be spaced over.

(g) BCD information - (Axx)

The prefix "A" attached to the number of character positions desired for the BCD information.

Unit Field:

The letters BR to display bright characters or blank for normal brightness level. If BR is used, the time field must be left blank.

Time Field:

The word FLASH for flashing information. If FLASH is used, the Units Field must be left blank.

Variable Field:

This field will contain the number of characters (N) in the message separated by a comma from the BCD information of the message. Blank spaces must be included in the count for the number of characters (N) and N must be a multiple of 4. The message may be composed of the numbers 0-9, and the letters A-Z. The special characters / (slash), , (comma), - (minus), * (asterisk) and . (period) may also be used. As noted, the message is limited to a maximum of 60 characters.

Usage:

To erase the complete matrix area involving messages enter the word "ERASE" in the value field and leave all other fields blank. To erase a complete line, regardless of how the total line was built up, enter the line number in the lower limit field, the word "ERASE" in the value field, and leave all other fields blank.

To erase a portion of a line, enter the word "ERASE" in the value field, the line number in the lower limit field, the character position number in the upper limit field from which to start erasing and the number of characters to erase in the variable field. All other fields will be left blank.

Operator: <u>MESSAGE DISPLAY</u> Mnemonic: <u>MESG*</u>

Class: <u>UTILITY</u>

Description:

The MESSAGE DISPLAY operator will transmit a BCD message to the Display System. This message will be displayed on the CRT in a specified number of character positions of a selected line. The area of the CRT usable for messages consists of a matrix of 36 lines (1-36) and 60 character positions (1-60) per line. The statement will save the specified BCD message in a labeled BCD table. The statement also allows a message to be displayed by simply referring to a labeled BCD table. Any displayed message can have the characters flashing or non-flashing and, if non-flashing, the characters can have two brightness levels. The operator provides for erasing any line or a particular portion of a line.

Fixed Fields:

<u>Operator Field:</u>

The mnemonic MESG will be entered.

<u>Condition Field:</u>

Unused.

<u>Value Field:</u>

The label of the BCD table for the message information or the word "ERASE" will be entered.

<u>Lower Limit Field:</u>

The matrix line number for the message will be entered (1-36).

<u>Upper Limit Field:</u>

The character position on the selected line for the start of the message will be entered (1-60).
Caution: Be sure enough character positions are available to hold the message specified without overlapping other information on the line.

Operator: NAME   Mnemonic: NAME*

Class: UTILITY

Description:

The NAME operator will be used to attach a label to the ITCL test procedure and to enter BCD information about the test procedure. This BCD information identifies the test procedure by containing any pertinent information necessary for identification. Whatever BCD information is entered will be used to identify the test procedure on the Event Trail Data tape.

Fixed Fields:

Operator Field:

The mnemonic NAME will be entered.

Variable Field:

The name of the test procedure will be entered as a word with up to 4 alphanumeric characters, the first of which must be alphabetic. If BCD information is entered, it will be entered following the 4 character name and separated from it by a comma, continuation cards may be used. All alphabetic characters, all numeric characters, and the special characters / (slash) and - (dash) are allowed. All other characters are illegal.

Operator: <u>PERCENT COMPUTATION</u>   Mnemonic: <u>PCT</u>

Class: <u>UTILITY</u>

Description:

This operator provides a means to compare data from different sources to a selected percent of full scale. The data that exceeds the tolerance will be flagged.

Fixed Fields:

<u>Operator Field:</u>

The mnemonic PCT will be entered.

<u>Value Field:</u>

The desired percentage tolerance will be entered. If left blank, a branch to the test conductor will be initiated with the necessary messages to allow a decision on what percentage tolerance he chooses.

<u>Upper Limit:</u>

The length of the tables of data to be compared will be entered.

All other fixed fields will be blank.

Variable Field:

Label of first data table, label of second data table, storage location of the out of tolerance measurements shall be entered.

Operator: <u>REMARK</u> Mnemonic: <u>REMK</u>*

Class: <u>UTILITY</u>

Description:

The REMARK operator enters explanatory material for a test statement. As many REMK operators as desired may follow a given test statement. This statement does not convert into machine language and is not displayed, but is used for descriptive information on the procedure hard copy.

<u>Fixed Fields:</u>

<u>Operator Field:</u>

The mnemonic REMK will be entered.

The comments will be entered starting in the fixed (value) field.

Operator: RESERVE Mnemonic: RESV*

Class: UTILITY

Description:

The RESERVE operator will provide for the reservation of the specified number of sequential storage cells and will attach the specified label to the first of these storage cells.

Fixed Field:

The number of sequential storage cells to be reserved will be entered in the value field. The quantity is left justified.

Operator Field:

The mnemonic RESV will be entered.

Step Field:

The label of the first location of the sequential storage cells will be entered. The label may have up to 4 alphanumeric characters, the first of which must be alphabetic.

Operator: RETURN Mnemonic: RETN*

Class: UTILITY

Description:

The RETURN operator will cause the termination of a subroutine and return to where it was requested.

Fixed Fields:

Operator Field:

The mnemonic RETN will be entered.

All fixed fields will be left blank.

Variable Field:

The variable field will be left blank.

Operator: REWIND   Mnemonic: REWD

Class: UTILITY

Description:

This operator provides the capability to rewind any specified tape drive to the load point of the tape.

Fixed Fields:

Operator Field:

The mnemonic REWD will be entered.

Condition Field:

The number specified to identify the desired tape unit will be entered.

All other fields will be left blank.

Operator: SKIP Mnemonic: SKIP

Class: UTILITY

Description:

The SKIP operator provides a means for locating information to be read into memory from a tape unit. In order that the location of the read heads is known on the specific tape and tape unit, an ENTR or REWD operator must be used prior to the SKIP operator in the test procedure.

Fixed Fields:

Operator Field:

The mnemonic SKIP will be entered.

Condition Field:

The number specified to identify the desired tape unit will be entered.

Value Field:

The quantity of files or records to be skipped will be entered in decimal notation.

Unit Field:

The letters R or F will be entered to define records or files to be skipped.

All other fixed fields and the variable field will be left blank.

Operator: SUBROUTINE   Mnemonic: SUBR

Class: UTILITY

Description:

This operator makes it possible to code standard subroutines in ITCL language as well as machine language. These subroutines can be compiled or assembled independent of the main program which uses them.

Fixed Fields:

Operator Field:

The mnemonic SUBR will be entered.

Condition Field:

"I" - The subroutine which follows is coded in ITCL.

"S" - The subroutine which follows is in symbolic.

Value Field:

An alphanumeric label for this subroutine.

Variable Field:

The variable field contains a list of arguments separated by commas which the subroutine needs to operate satisfactorily.

If no arguments are needed, this field is left blank.

Operator: <u>TERMINATE</u> Mnemonic: <u>TERM</u>

Class: <u>UTILITY</u>

Description:

This operator terminates the test procedure and puts the equipment back into the original state of operation. It also turns control over to the monitor system.

Fixed Fields:

Operator Field:

The mnemonic TERM is entered.

All other fields are left blank.

Operator: WRITE   Mnemonic: WRIT

Class: UTILITY

Description:

The WRITE operator will provide the means of getting data out of the computer memory and do one of the following: (1) display this information on a CRT, 60 characters per line with a 36 line maximum, (2) display this information on line printer, 120 characters per line, (3) write either a binary or BCD tape.

Fixed Fields:

Operator Field:

The mnemonic WRIT will be entered.

Condition Field:

"D" - Indicates the CRT for output.
"P" - Indicates the line printer for output.
A numeric number indicates the number of the tape drive.

Value Field:

The label of the associated format specification will be entered. This field is left blank if a number was entered in the condition field, and a binary tape is written with a maximum of 4095 words.

Lower Limit Field:

This field is used on display output only to indicate the line number for the output information to start on.

Upper Limit Field:

The number of lines of output will be entered from the display output only.

The rest of the fixed fields are blank.

Variable Field:

This is the same as in the operator called ENTER.

APPENDIX

INSTRUMENTATION AND TELEMETRY CHECKOUT EQUIPMENT

SATURN IC STAGE

QUALITY AND RELIABILITY ASSURANCE LABORATORY

MARSHALL SPACE FLIGHT CENTER

The Instrumentation and Telemetry Systems on the Saturn IC and the related ground equipment used in checkout at the MSFC Quality and Reliability Assurance Laboratory were reviewed to establish a criteria for the Instrumentation and Telemetry Checkout Language. A short resume of the salient features of these systems are included here for reference.

1. STAGE EQUIPMENT

Figure A-1 shows the typical airborne systems as used on the Saturn vehicles. They include the following systems:

1. Universal Measuring Adaptors and Remote Automatic Calibration System
2. Signal Multiplexers
3. Frequency Modulation (FM) RF Transmitters
4. FM and FM/FM Modulators
5. Single Side Band Modulator
6. Digital Data Acquisition System (Pulse Code Modulation)

1.1 Pulse Code Modulation/Digital Data Acquisition System (PCM/DDAS)

The transducer outputs (data points) are connected to the measuring racks which contain signal conditioner/amplifiers that condition the signals to the standard 0 to 5 volt levels. The measuring racks contain provisions for remote calibration. The measuring rack outputs are distributed through the Measuring Distributor to the input points of the multiplexers.

The Model 270 multiplexers are time-division multiplexers that gate the data points through the multiplexer to convert the parallel inputs into a serial pulse amplitude modulated (PAM) wave train.

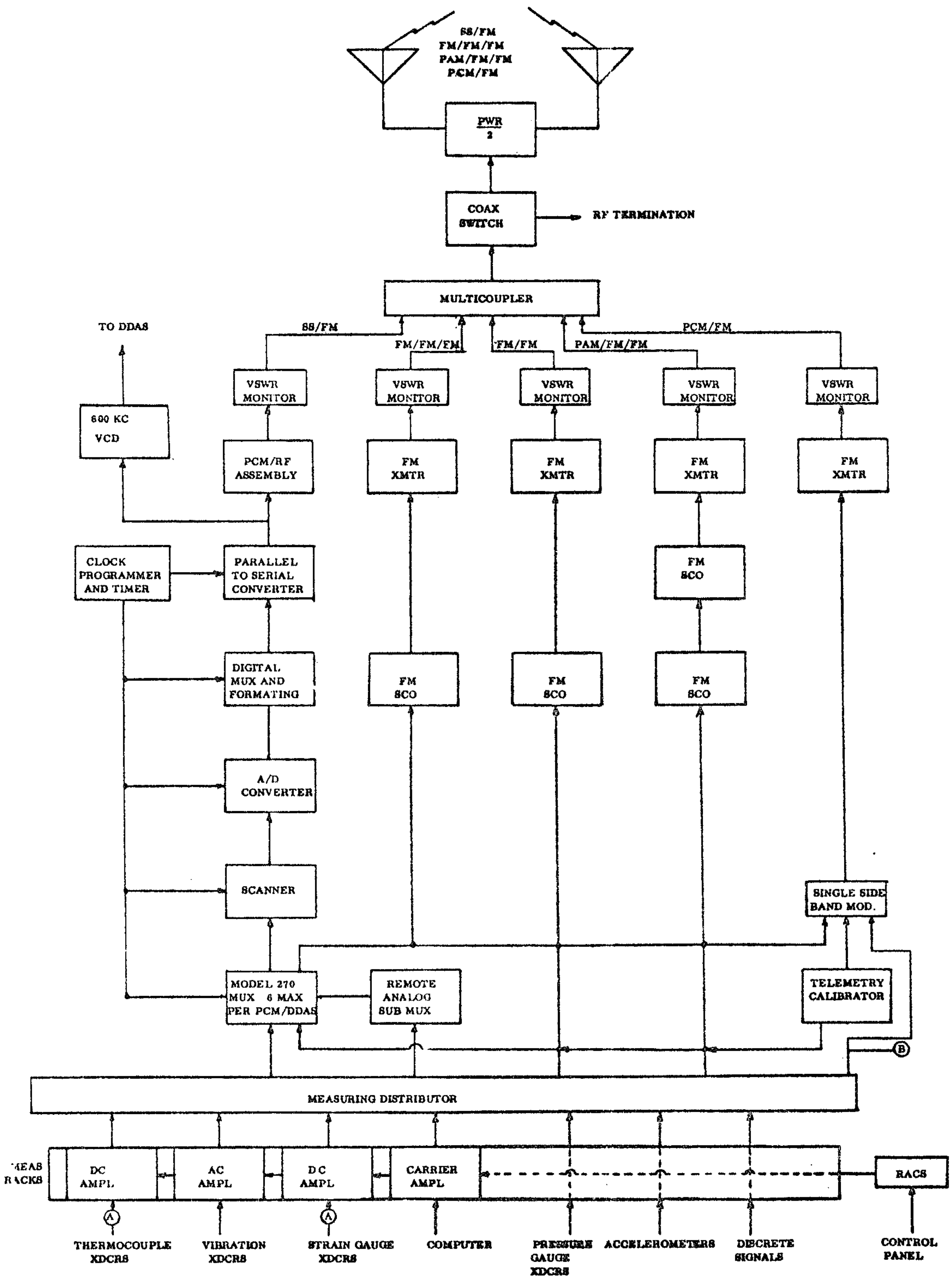

Figure A-1. Saturn Instrumentation Systems.

The multiplexer outputs (the Saturn V S-IC has four) are the inputs to the scanner. The scanner is essentially another multiplexer that interweaves or combines the PAM wave train into one wave train that is the input of the analog to digital (A/D) converter.

The A/D converter converts the PAM analog wave train into a 10 bit binary representation of each analog value. This 10 bit word is combined with other digital data inputs and appropriate frame and master frame identification by the Digital Multiplexer. The parallel word output of the digital multiplexer is converted into a serial train and presented to the PCM/FM RF Assembly for transmission and to the 600 kc voltage controlled oscillator to provide the DDAS output that is routed by coaxial cable to the DDAS ground station.

The Model 270 Multiplexer is a time-division multiplexer which accepts a maximum of 254 data inputs. There are 30 primary channels of which 27 are used for measurement data and three are used for amplitude and frame reference identification.

The basic primary channel sample rate is 120 samples per second for each channel. Twenty-three of the 27 data channels are submultiplexed to provide 10 subchannels that are sampled at a rate of 12 samples per second each. All 27 primary channels may be submultiplexed externally by using a Remote Analog Submultiplexer assembly. As each of the primary channels (data points) are sampled 120 times per second, the output of the multiplexer is an amplitude modulated pulse train of 3600 pulses per second. When channels 24 through 27 are submultiplexed with a Remote Analog Submultiplexer, the maximum data point input increases from 234 to 270.

The Model 270 multiplexer provides two outputs; one, with a DC voltage offset pedestal, is transmitted through the 70 KC ± 30% channel of the PAM/FM telemetry system. The other, without pedestal, is fed to the scanner which interlaces the parallel multiplexer outputs (up to 6 maximum) into a serial train of 7200 samples per second which go to the PCM/DDAS.

An example of the scanning mode of the scanner is illustrated by the Saturn V S-IC system. It has 4 multiplexers, 3 of which are scanned with every third frame (1200 samples/sec.) being accepted. The fourth is sampled at the basic rate of 3600 samples per second. This provides a basic rate of 7200 samples per second of the sample wave train in which every data point has been scanned and presented to the scanner output at least once in 1/4 second.

The 7200 sample per second pulse amplitude modulated wave train output of the scanner goes to the analog to digital converter, which converts each sample into a 10-bit binary word that represents the analog value. The output of the converter is presented to the Digital Multiplexer.

The digital multiplexer inserts words from digital measurement sources into the word string and formats the identification channels. The output of the digital multiplexer is converted from a parallel to a serial PCM wave train (72,000 bits/sec. basic rate), which is presented to the PCM RF assembly and to the DDAS 600 KC voltage controlled oscillator (VCO). The PCM RF and the 600 KC VCO outputs are frequency modulated by this data wave train and transmitted to their respective ground stations.

1.2 Remote Automatic Calibration System (RACS)

The automatic calibration system enables a remote checkout of the flight instrumentation system and equipment used for maintaining the functional readiness of the vehicle.

Each of the signal conditioning modules in the Universal Measuring Adapters contain a range card which includes transducer simulation circuits for testing the module calibration. Two control relays are used to switch the high (HI) mode and low (LO) mode range of the calibrated range of the measurement. The (RUN) mode returns the measurement to its normal operating position.

The RACS is designed to remotely control a maximum of 1080 relays for the calibration of the S-IC. It is designed to handle a maximum of 540 measurements which are divided among 27 racks of 20 channels each.

1.3 Telemetering Calibrator

A Telemetering Calibrator is used in conjunction with each telemetry system on board each stage. The purpose of the telemetering calibrator is to provide a calibration control and reference signal source for a maximum of six FM/FM telemetry systems and three SSB/FM telemetry systems. Two types of calibration sequences are provided; preflight calibration initiated by ground support equipment (GSE), and inflight calibration initiated by GSE or by the vehicle programmer.

When calibrating the FM/FM telemetry systems, the calibrator receives a voltage of +5 VDC from the measuring system power supply, and divides this into step voltages of 0, 25, 50, 75, and 100 percent of 5 volts, simultaneously, the calibrator supplies a calibration control signal to each telemetry link which transfers the input of each from a data line to a calibration bus. The five steps are applied to each link in sequence, with each step held for a duration of 140 milliseconds. The complete calibration cycle for six telemetry systems sequences in 4.5 seconds.

Calibration of the SSB/FM telemetry systems is accomplished in the same manner with the three links being calibrated in sequence. The difference is that the calibration signal is a 1700 Hz, 1.0 VAC P/P sine wave instead of DC step voltages.

Preflight and inflight calibration is also accomplished similarly. The difference being that the calibrate initiate signal for inflight calibration is generated by the airborne programmer rather than GSE.

2. ELECTRICAL SUPPORT EQUIPMENT

Figure A-2 shows the electrical support equipment associated with the instrumentation and telemetry system.

1. Telemetry Ground Station (RF Receiver and Switching)
2. FM Ground Station (Discriminator and Switching)
3. Digital Data Acquisition System
4. Telemetry Digitizing System
5. DDAS Computer Interface

2.1 Telemetry Ground Station

The Telemetry Ground Station has the capability of processing the following types of telemetry transmission; FM/FM, FM/FM/FM, PAM/FM/FM, SS/FM, and PCM/FM.

The Systems Selection Control Panel provides a means to control the setup of the system either by manual switching or by computer control. This panel routes the receiver outputs to the desired tape recorder tracks and discriminators. The discriminator band pass and low pass filter outputs are also controlled in that they may be routed to recorders, counters, and other output devices.

Computer control is provided for the 11-point calibrator and the frequency counter. The 11-point calibrator is used to establish calibration of the discriminators. The frequency counter is used to count the transmitter frequencies and the IRIG channel frequencies (BPF) during tests.

The open loop RF system consists of two parallel systems of a helical antenna, preamplifier, and multicoupler feeding a bank of six receivers each. The receiver outputs are routed by the System Selection Control Panel to the selected discriminators. The single side band receiver outputs are hardwired to the

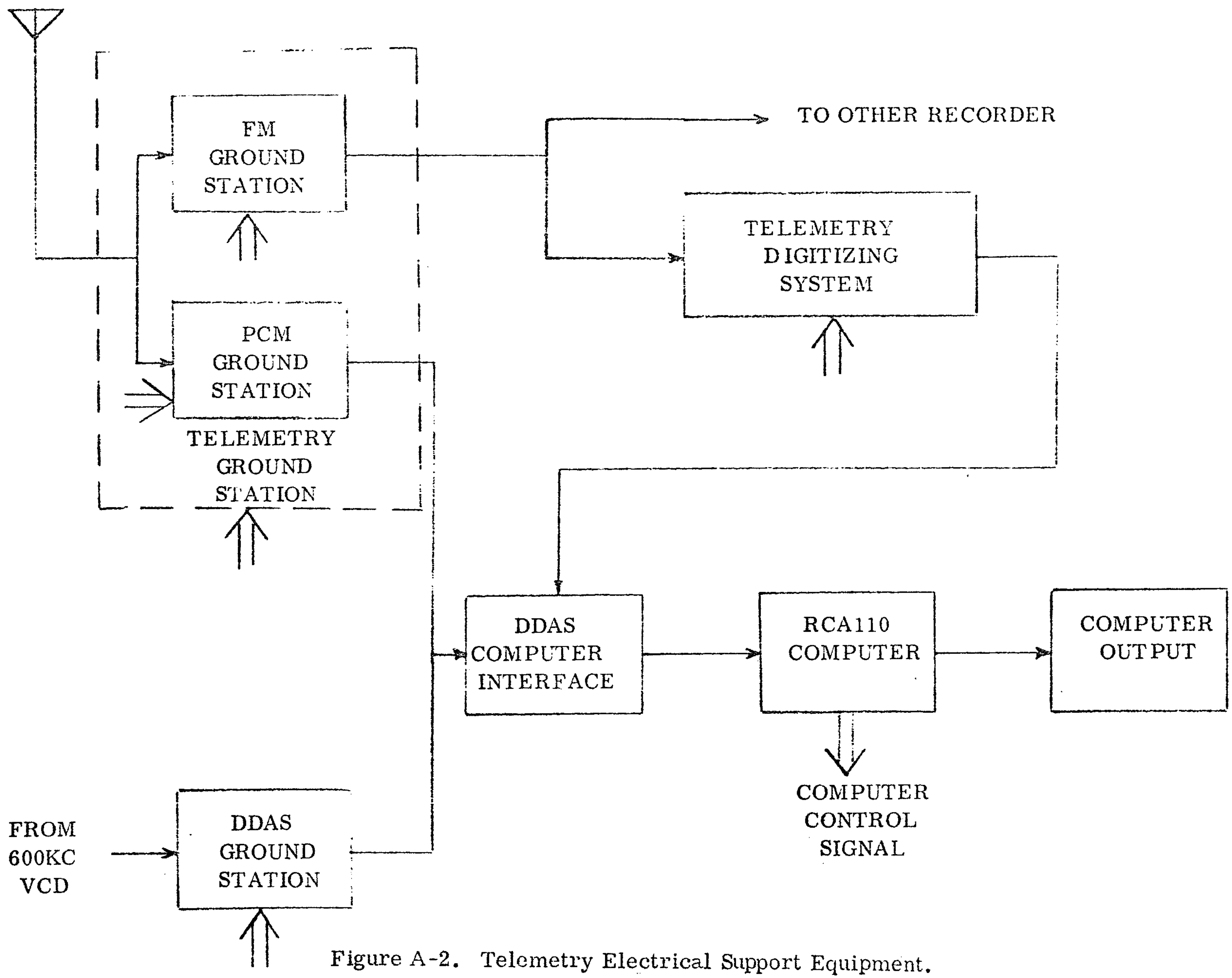

Figure A-2. Telemetry Electrical Support Equipment.

single side band demodulator with parallel outputs to the receiver patch panel for recording.

The discriminator bank contains standard IRIG channels, and 70 KC ± 30% discriminators as well as 120 KC reference discriminators for tape speed compensation of the tape recorder playback data. The discriminator bank is used to process the FM/FM/FM, and PAM/FM/FM data. The following paragraphs discuss the functions performed in each section of the ground station.

2.1.1 FM/FM Ground Station. The FM/FM data is reduced from the receiver video by the standard IRIG discriminators. The output of the discriminators is available to the analog recording equipment and to the Telemetry Digitizing System (TDS) for conversion to the DDAS format for entry into the RCA 110A computer through the computer interface in the DDAS ground station.

2.1.2 FM/FM/FM Ground Station. The FM/FM/FM composite signals are processed with the same equipment as described for the FM/FM signals, except that additional discrimination is performed prior to feeding the signals to the standard IRIG discriminators. The output of the FM/FM/FM station is made available to the analog recording devices and to the Telemetry Digitizing System as is the FM/FM station output.

2.1.3 SS/FM Ground Station. The single side band receiver outputs are hard-wired to the single side band demodulator and to the receiver patch panel for recording on the tape recorder. The single side band demodulator reduces the data to its original condition to be recorded on the oscillographic recorders. All single side band data reduction is done manually.

2.1.4 PAM/FM/FM Ground Station. The PAM/FM signal from the receiver is sent to the 70 KC ± 30% discriminators. The PAM output of the discriminators is made available to the PAM decommutator (Model BFJ-3) and to the input of the Telemetry Digitizing System (TDS) for conversion to the DDAS format for entry into the computer interface panel in the DDAS Ground Station.

2.1.5 PCM/FM Ground Station (Model TRS-1). The Model TRS-1 PCM/FM Ground Station is very similar to the Model DRS-1 Ground Station. It does not have a source selector panel or a computer interface. Its purpose is to provide analog and digital outputs for recording or visual (quick-look) monitoring. The operating functions performed will be discussed in the section of the PCM/FM Ground Station (Model DRS-1).

2.2 PCM/FM Ground Station (Model DRS-1)

The Model DRS-1 PCM Ground Station is similar to the Model TRS-1 described above, but its primary purpose is to provide data entry to the computer rather than "quick-look" or manual data reduction data. The vehicle RF signal is transmitted via coax cable rather than via radio link as with the Model TRS-1.

The Source Selector Panel has seven inputs and one output. The first five are numbered 1-5 and the last two are labeled SIMULATOR and ANTENNA. The input selection can be controlled manually or automatically.

When in the ANTENNA position, the PCM/FM RF carrier is demodulated by the receiver and the serial digital data wave train is fed to the synchronizer.

The synchronizer shapes and restores the incoming data to provide a clean, noise-free signal in NRZ(S) format output. It also regenerates the clock frequency to be used for logical functions in the remainder of the station. The restored signal is then applied to the demodulator block of the diagram. Here the signal is demodulated into the digital words and word addresses and synchronization is established with the airborne system. These digital words with their identifying addresses are presented to the computer interface for entry into the computer and to display equipment for "quick-look" or recording capability in analog or digital format.

The simulator provides a signal in the PCM/DDAS format for setting up and testing the station. It provides a means of constructing the Saturn format using known synchronization words and data channel words to prove the calibration of the station.

2.3 DDAS Ground Station

The DDAS station is similar to the PCM/FM ground station described above. The DDAS input signal is the same as the PCM/FM signal except that it is modulated on a 600 KC carrier and input to the special receiver via a coax cable from the vehicle.

During normal checkout procedures the vast majority of instrumentation data is obtained via the DDAS Ground Station. This ground station also serves as the instrumentation data interface between the computer and the stage and provides outputs in both digital and analog forms for use in remote displays in locations such as the control room.

2.4 Ground Station Tape Recorders

The Telemetry Ground Station has two tape recorders. One to support the telemetry ground stations and one to support the DDAS.

These recorders are 14-track, wide-band machines with 10 channels of direct record/reproduce and 4 channels of FM record/reproduce electronics.

Frequency response of the direct channels are flat ± 3 db over the range of 400 cps to 1.5 Mcps. The FM channels are flat ± 3 db over a bandwidth of DC to 400 Kcps.

2.5 DDAS Computer Interface

The majority of data available to the computer during Instrumentation and Telemetry systems checkout is introduced through the DDAS Computer Interface Panel. The split computer interface presents the decommutated DDAS data and the corresponding TDS data simultaneously to be accepted by the computer.

To read the measurements into the computer, the computer generates a data request signal and the address of the data point. The DDAS, TDS, and PCM data is presented at the gates of a storage register and the addresses is presented to a comparator. When the computer requested address and the data address are the same, the data is gated into a 40-bit storage register and a data ready signal is sent to the computer. The last requested data remains in the storage register until a new request is initiated.

The RCA-110A puts the data into memory in serial form, two words at a time. The 4 words (40-bits) are accepted on the basis of one address comparison. These words are; the addressed word plus 1 (A+1), the addressed word (A), (A-1), and (A-2). When acquiring PAM data from the TDS, the TDS generated word is placed in the A-2 position. The RCA-110A initially stores this data (2 words) to a 24-bit memory location, which must be sorted and realigned prior to any calculations or comparisons.

2.6 Telemetry Digitizing System (TDS)

The function of the TDS is to digitize selected (up to 68) analog signals into the PCM/DDAS format to be compared to the PCM data, DDAS data and predicted values. The parallel data output is supplied through the DDAS computer interface to the RCA 110A computer.

The analog input may be real-time output from the discriminators or playback from previously tape recorded data. The selected channels of data are patched from the ground station output patch panel to the input of the Telemetry Digitizing System.

The TDS can be reduced into the following 10 functional areas:

1. Input attenuators.
2. Multiplexer system.
3. Analog-to-digital converters and registers.
4. Analog and synchronization code gating unit.
5. Output register.

6. Displays.
7. Programmer.
8. Synchronizer.
9. Control panel and manual reset.
10. Printer.

A short description of the function of these areas follows:

2.6.1 Input Attenuators. The input attenuators (68 utilized) attenuate all analog inputs to a level (3.896 volts) acceptable to the multiplexer system. The outputs of the input attenuators are gated into the multiplexer system.

2.6.2 Multiplexer System. The multiplexer system samples the data of the selected 68 input channels, time-shares the information and transfers the sampled data to the coder.

The multiplexer system consists of two identical multiplexers, each time-shares 34 channels of the input analog voltages. The logic operation of the multiplexer units is controlled by the word selection logic and the system synchronizer. The sample rate of the multiplexer system is synchronized with externally supplied word rate pulses.

The output of the multiplexer is a pulse amplitude modulated signal sent to the coder for digitizing. In addition, the multiplexer sends command pulses to control the coder operation.

2.6.3 Analog-to-Digital Converters and Registers. The A-D converters (coders) receive the PAM signals from the multiplexers and convert the analog data to digital words. These digital words are then serially gated into registers where they are converted into parallel form.

The coder unit consists of two identical, but independent, A-D converters which receive their input from their related multiplexers. The 11-bit digital word is generated by the successive approximation method and is then put into the register. The register accepts the digital word in serial form, but the output is in parallel form.

2.6.4 Analog and Synchronization Code Gating Unit. The analog and synchronization code gating unit accepts synchronization words and external digital words from the word delay unit along with the digitized analog data received from the coder registers. These three quantities are gated together to form a PCM wave train to be fed to the serial code output register, the printer register and the binary display registers.

2.6.5 Output Registers. The output register accepts parallel binary data from the analog and synchronization code gating unit and bit rate from the bits-per-word counter. The parallel data is converted to serial form. Serial data, bit rate, and parallel data are available as outputs, but only parallel data is transferred to the DDAS computer interface.

2.6.6 Displays. The TDS utilizes three visual displays for quick-look capability. One for decimal readout and two for binary readouts. Four rotary switches associated with each display unit enable an operator to select onboard data from a particular group, multiplexer, frame and channel to be displayed.

2.6.7 Programmer. The programmer provides a means of inserting incoming analog data into the same time slot as identical PCM data and to provide identification or synchronization words for the digitized data. The proper analog voltages must be inserted in the same group, multiplexer, frame and channel as the corresponding PCM data so that a comparison of the two signals can be made.

The programmer consists of a 1224 terminal patch panel, word selection logic, reset logic, four program counters, and a two word delay unit.

The purpose of the program counters is to generate time slots in the TDS identical to the time slots generated by the onboard PCM package. The outputs of the counters are also present in the Display Panel to select binary and decimal displays.

The analog input voltages are inserted in the correct time slots by the patch panel. The patching of the patch panel also generates the frame identification or synchronization words.

The word selection logic provides a means of gating query pulses from the patch panel to the multiplexer.

The 2-word delay unit consists of 14 different channels. Each channel delays the signal it carries by two word times. Word rate is supplied to the 2-word delay unit by the bits-per-word counter.

2.6.8 Synchronizer. The function of the synchronizer is to provide synchronization between the TDS and externally supplied pulses. Upon receipt of an external sync pulse, the synchronizer issues timing commands to the TDS operation control, which is in sync with the external signal.

The external signals are; (1) Master pulse, (2) System word one, and (3) word rate or bit rate. If external word rate is supplied, a phase correcting VCO generates bit rate, if bit rate is supplied, a bit rate counter generates the necessary sync pulses. Each of the input pulses are supplied to the synchronizer through a patch panel. By patching, the incoming master pulse can be delayed or shifted by up to nine bit times. This flexibility is provided to synchronize the master frame sync pulse and the system word number one. A bit-rate offset can also be obtained by changing the patching on the set and reset sides of the patch panel.

2.6.9 Control Panel and Manual Reset. The control panel contains switches that control the power input to the system, the mode of operation, the number of channels to be printed, the frequency range of the system, and system reset.

2.6.10 Printer. The printer is used to print out selected channels of data in decimal form. Five channels can be selected for print out. One channel can be selected on the front panel by means of four print select switches. This channel is also read out on the decimal display. The other four channels to be printed must be selected by patching on the patch panel.

2.7 Remote Automatic Calibration System (RACS)

The airborne RACS are controlled by the RACS control panel. This control panel can be controlled remotely by a PCU or locally on the front panel. It enables a technician to select the desired measurement module in the vehicle and the calibration mode (HI, LO, RUN). Any of the channels can be selected and energized in any of the three modes individually or in random sequence. When the control signal is initiated, it is transmitted to the vehicle via the umbilical connectors. Both the rack-select and channel-select portions of the control panel have "ALL" buttons which allow the following conditions.

1. All 20 channels in any one rack in HI, LO, or RUN simultaneously.
2. All channels in all racks in HI mode.
3. Any one channel in all racks in HI mode.
4. Any one channel in any one rack in HI mode individually.

The PCU's are portable units that are operated by "onboard" checkout personnel. They have the following control switches and status indicators.

Control Output	Discrete Output from Computer
1. Power ON/OFF switch	1. PCU ENABLE
2. Standby	2. ABOVE status
3. Finish	3. BELOW status

Control Output	Discrete Output from Computer
4. Octal address selector	4. GO status
5. Mode (RUN, HI, LO) selector	5. STIMULATE status
6. Computer request	6. WRONG DIRECTION status
	7. COMPUTER AVAILABLE

These control signals are decoded in the airborne selector rack assembly which places the addressed rack and channel signal conditioner in the requested mode.

When the RACS control panel is switched to the automatic position, the computer controls its operation.

Two examples of the usage of this system are: (1) testing the system from the transducer through the DDAS output, and (2) adjusting the amplifier modules to predetermined calibration points.

To end-to-end test the transducer data path, the technician, after connecting the PCU, would dial the signal conditioner address and RUN mode and request the computer. The computer would begin scanning the requested data point through the DDAS interface and light the STIMULATE indicator on the PCU. The technician would stimulate the transducer (with heat gun or dry ice in the case of a temperature transducer) and the computer would scan the data point and check for the change of data due to stimulation.

To test the calibration amplifier modules, the technician dials the desired rack and channel address and mode (HI or LO) and requests the computer. The computer scans the data point and compares its value to a calibration value previously entered into the memory and lights the applicable status light on the PCU (GO, ABOVE, or BELOW). If "ABOVE" or "BELOW", the technician changes the adjustment until a "GO" indication is received. A "WRONG DIRECTION" indication is received should the technician make the adjustment in the direction to worsen the comparison of the received data value to the expected data value.

As this is a man-machine testing procedure the speed and efficiency of the combination is limited by the technician. Therefore; the program should allow for exit options in order to more fully utilize the computer.

2.8 Voltage Measuring System (VMS)

The Voltage Measuring System provides a method of checking the calibration of the DC amplifiers in the Universal Measuring Adapter (UMA) racks. It consists of a programmable power supply, manual control panel, logic control chassis and a patch panel for signal distribution.

Each UMA rack contains 20 amplifiers. The UMA rack is selected by patching and output cable connection. The 20 individual amplifiers can be selected manually with the manual control panel or automatically with the RCA 110A computer. The manual mode is used for trouble-shooting and calibration of the VMS.

The individual amplifier gain can be checked by comparing the known input voltage, from the VMS, to the amplifier output voltage as monitored by the RCA 110A computer through the DDAS.

Transfer of control from the RCA 110A computer to the manual control panel is accomplished by manually exchanging the interconnecting cables.

2.9 DDAS Calibrator

The purpose of the DDAS Calibrator is to verify the calibration of the onboard DDAS. This is accomplished by applying a known voltage to the 4 61-pin input connectors. The output of each measurement is read through the DDAS ground station with the RCA 110A computer or by DACE. The equipment consists of a precision power supply, a digital voltmeter and a distributor panel.

The DDAS Calibrator voltage is set in 5 steps from 0 to 5 VDC. (0.0, 1.25, 2.5, 3.75, 5.0). These analog input signals enter the 270 channel multiplexer portion of the onboard DDAS system and are digitized and sent to the DDAS ground station, and then to the RCA 110A computer for display. The computer display is compared to the digital voltmeter display for calibration verification.

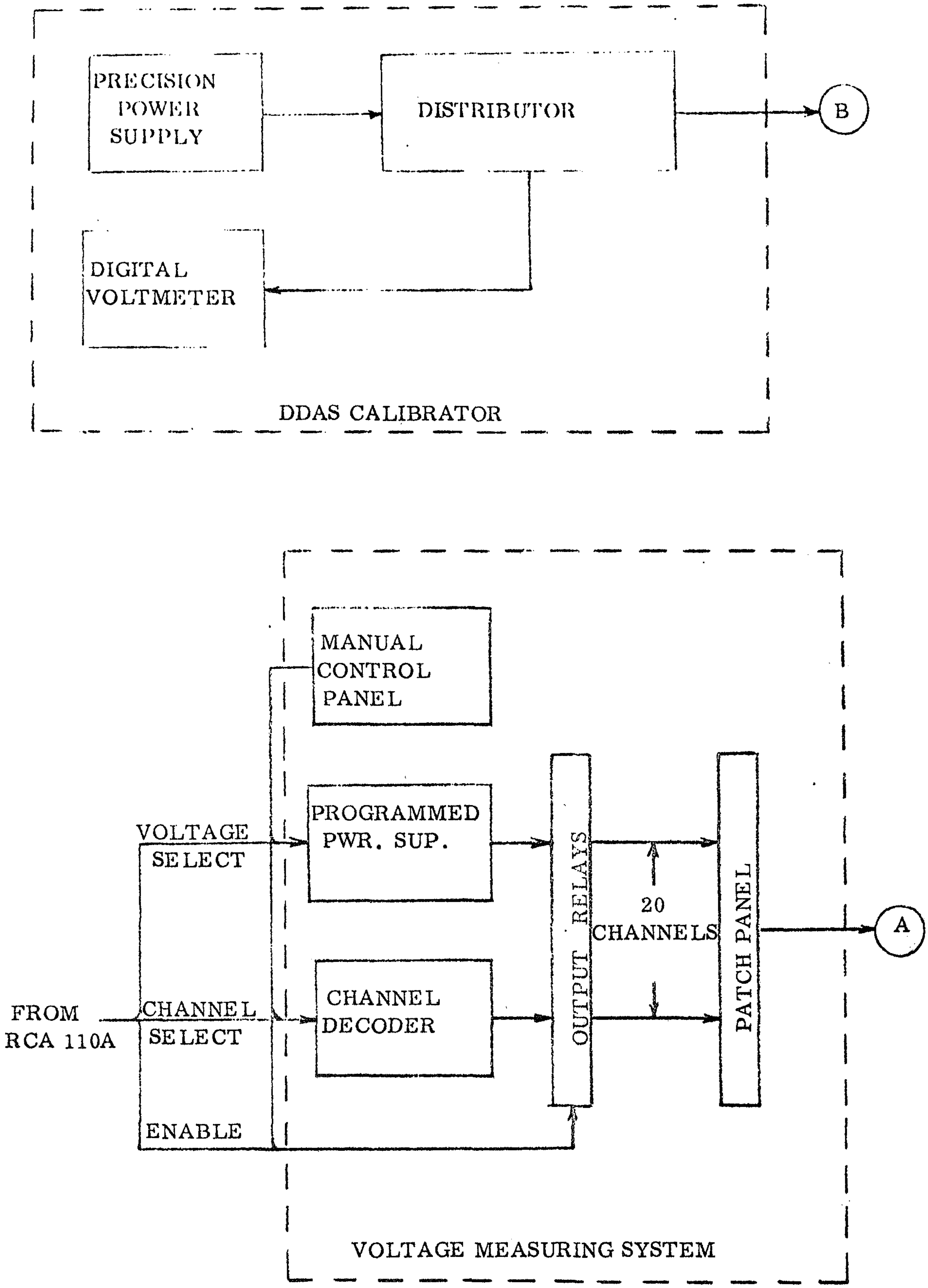

Figure A-3. Telemetry Calibration Equipment.